Jan. 19, 1954 S. C. ROCKAFELLOW 2,666,887

ELECTRIC ARC DEVICE

Filed Feb. 3, 1951 3 Sheets-Sheet 1

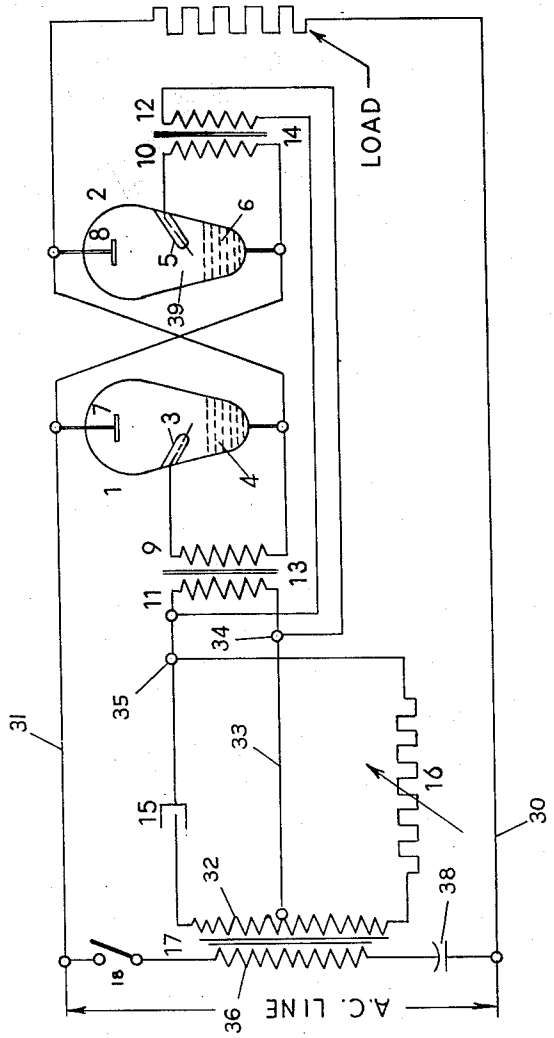


FIG. 1

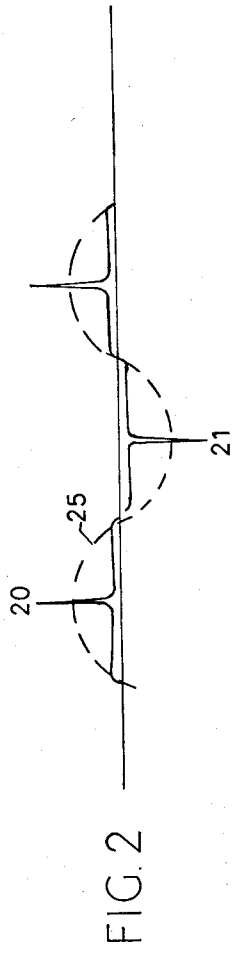


FIG. 2

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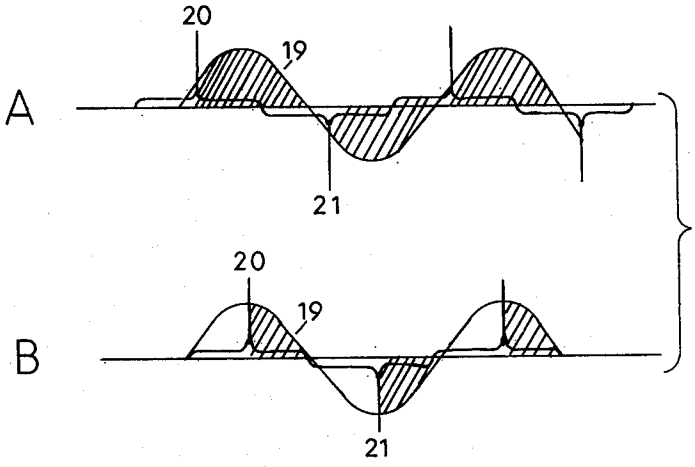


FIG. 3

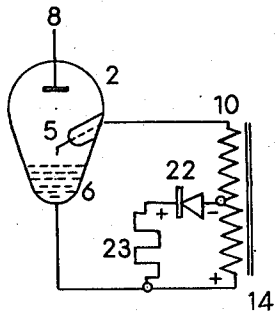


FIG. 4

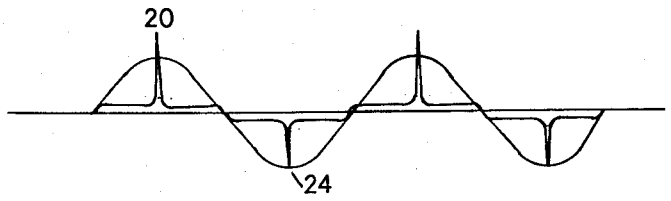


FIG. 8

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ELECTRIC ARC DEVICE

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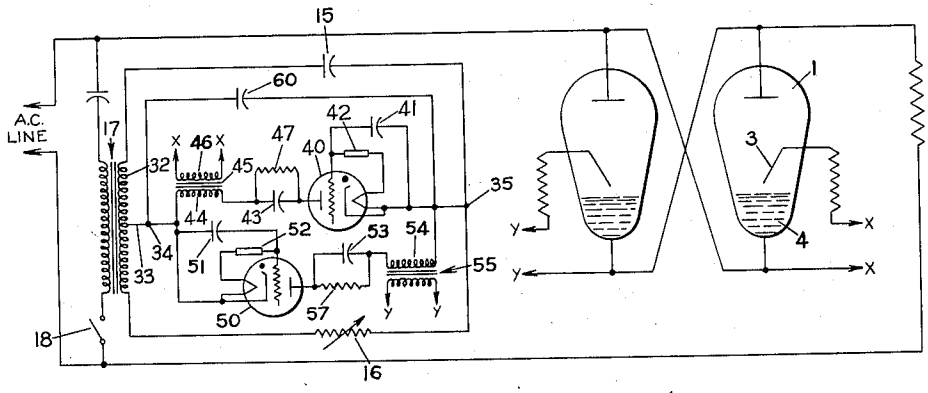


fig. 5

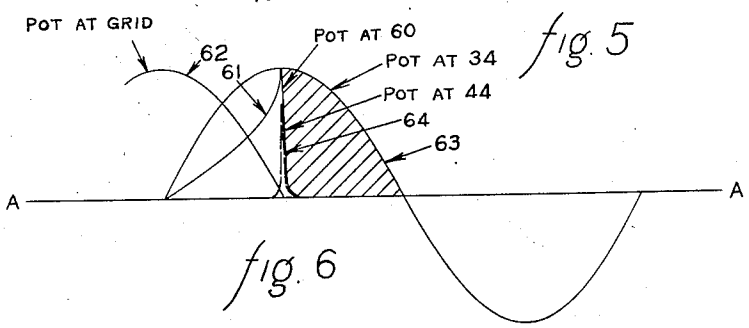


fig. 6

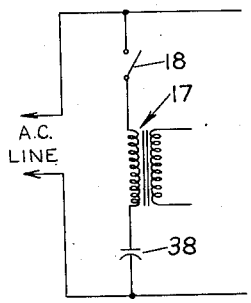


fig. 7

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ELECTRIC ARC DEVICE

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Application February 3, 1951, Serial No. 209,282

3 Claims. (Cl. 323—24)

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This invention relates to electric arc devices and has particular relation to an improved device for initiating a flow of current between a pair of conductors and has secondary reference to means including said initiating means controlling the point on the wave form of an alternating current supply at which the arc discharge commences in order thereby to control the magnitude of the average current applied to a load.

In present forms of devices for initiating flow of current between a pair of conductors, such as in the common ignitron or as in the device shown in the United States Patent to Slepian, No. 2,069,283, it has been necessary to supply a relatively large quantity of current for starting purposes regardless of the requirements of the load being supplied by the starting device. Thus, where a relatively light load was involved, it has been necessary to add in parallel with said load sufficient load resistors to cause the drawing of enough current to meet the minimum requirements for starting purposes. Thus, on these cases more current has been supplied to the system than was actually required by the load, with consequent wastage of current and the necessity of providing larger sizes of tubes than would actually be required by the current through the load.

Further, in present systems wherein the starting electrode is initially immersed in the mercury pool, it is believed that the starting function is effected in microscopic indentations in the coating on the starting electrode. The bottoms of such indentations are not wet by the mercury and this accordingly provides chambers of microscopic size in which arcing, and consequent ionization of the mercury, initially takes place. As the tube is used, the indentations become progressively larger and both more current and more voltage are required to effect ionization through all of said indentations simultaneously. Eventually, this requirement exceeds the supply and the tube fails.

It is accordingly desirable to provide a starting tube which requires only an infinitesimal amount of current so that the current supplied to the system need not exceed the amount actually required by the load. Further, it is desirable to provide a starting tube in which an adjustment may easily be made as the starting electrode deteriorates from use to compensate for such deterioration and thereby prolong the effective life of the tube.

These requirements are met by a combination including a tube in which the starting electrode

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is spaced away from the surface of the mercury pool, when said tube is in its normal position of operation, and wherein said tip of said starting electrode preferably is directly above the center of said mercury pool. The magnitude of said spacing is determined by the magnitude of potential which is conveniently available for application to the starting electrode together with the spacing required to effect ionization of the gas, commonly mercury vapor, with which the tube above the mercury pool is filled. Combined with this device are means controllably imposing onto the starting electrode a potential of high value and short duration.

The use of this type of starting device makes possible a number of advantageous circuits of greater simplicity and having parts of smaller sizes than is now possible with present starting devices. As one example of such advantageous circuit, there is herein disclosed a circuit by which there is obtained a high degree of accuracy of control over the magnitude of actual current flow through a load but in which the controlling means are extremely simple. In this circuit, there is provided means such that at a predeterminable point in the alternating current supply wave, there is caused an electric discharge between the starting electrode and the cathode pool, which discharge is of very short duration but which is effective to start ionization for permitting current flow between the main electrodes of the electric arc device. The potential used to start the initial discharge is many times greater than that used on present devices but it is extremely short in time and the average current consumed thereby is sufficiently low that an effective and simple control thereof, as above mentioned, is rendered possible.

By this means the electric discharge devices involved for small loads, inasmuch as they carry only the current actually required by the load, can be made much smaller than in present conventional circuits where the electric discharge devices, as ignitrons, must carry a materially larger current in order to operate. Thus, where, for example, the load requirement is only 16 amperes, the electric discharge devices, and auxiliary equipment, may in the light of the foregoing, obviously be made much smaller than in present circuits where a load resistor may draw 40 amperes and a thyratron of proper size may have a filament requiring 150 watts continuously in order to keep it hot and the thyratron will in addition require a relatively large filament transformer. Thus, the electric arc discharge device

here contemplated may be made and sold in conjunction with a small peak transformer as a relatively convenient and small package unit which will be of much less size and materially less expensive than is now characteristic of equipment for performing corresponding functions by conventional circuits.

A further requirement of the circuitry of this type is simple but effective prevention of backfiring, which sometimes occurs on negative cycles. In the apparatus herein disclosed, there is provided extremely simple means for this purpose which means are likewise made possible by the particular details thereof as described hereinafter.

In the drawings:

Figure 1 represents a diagram of a preferred form of the invention.

Figure 2 represents a time comparison of the potential supplied from the alternating current source and that applied to the starting electrodes.

Figure 3 in parts A and B thereof illustrate the different average currents supplied to the load by adjustment of the phase shift portion of the circuit.

Figure 4 represents an alternate circuit showing means positively preventing arc-back in arc discharge devices.

Figure 5 represents an alternate circuit showing a different means for applying a pulse of high value and short duration to the starting electrode.

Figure 6 is a graph showing the potential relationships in the various parts of the circuit of Figure 5.

Figure 7 is a fragmentary diagram of a portion of the circuit showing a still further modification thereof.

Figure 8 is a graph showing the potential relationships in the circuit of Figure 4.

GENERAL DESCRIPTION

The starting device which makes possible the above described beneficial results may be generally described as one wherein a starting electrode is spaced away from the surface of a mercury pool cathode a suitable distance sufficient to effect ionization, but within the range of the available potential, in combination with means by which there is applied across such starting electrode and cathode a momentary potential of a very high order. The tip of the starting electrode, is preferably, but not necessarily, placed directly over the center of the cathode pool.

In one particular circuit made possible by this improved starting device, a pair of such electric arc conducting devices are connected in back-to-back relationship with respect to each other, to the load and to a source of alternating current. The starting electrodes are connected to a source of high potential of short duration, which in one particular embodiment herein utilized for illustrative purposes is secured from the output of a peak transformer. Said peak transformer is supplied from the same alternating current source through a phase shift circuit by which the said peak transformer output may be shifted in its phase relationship with the alternating current source. In this manner, the conduction of the electric arc devices is initiated at any desired point with respect to the alternating current source and, thus, the average current passed through the load is readily controlled.

DETAILED DESCRIPTION

Turning first to the electric arc device, it may be of any conventional type involving a cathode pool material, as mercury, vaporizable and ionizable at low voltage and capable, when ionized, of carrying heavy current, such as shown in some detail in the United States Patent No. 2,069,283, to Slepian, excepting that here the starting electrode is spaced a short distance from the surface of the cathode pool. This distance is normally about one-fourth inch where a starting potential of about 5000 volts is to be used and mercury vapor constitutes the atmosphere within the tube, but this spacing with a mercury vapor atmosphere in the tube may vary from about one-eighth inch to about one-half inch. In any event, such spacing is sufficient that the arc passing between the starting electrode and the cathode will ionize the gas within the tube and it need not be materially greater than such amount. Thus, this spacing will be such, that depending upon the gas used as the atmosphere within said tube, the peak voltage will usually be between about 5000 volts and about 15,000 volts. However, this range is illustrative only and not limiting.

More specifically, in one particular instance here utilized for illustrative purposes, the alternating supply source is 115 volts, and the peak voltage imposed by the peak transformer across the starting electrode of the cathode pool is about 10,000 volts. The current flow through the starting electrodes is negligible, of the order of a few micro amperes. The actual power drawn to the starting electrodes will in the ordinary case average about one watt for both of the back-to-back connected tubes herein shown. About 40 to 50 watts input is required to produce this wattage at the starting electrodes due to losses in peak transformer and in the phase shift circuit.

It is thus seen that while the voltage for starting the operation of the arc discharge device is relatively high the current flow is negligible and hence the wattage is very low. This is effective to start the necessary ionization but it still permits the use of the relatively simple control apparatus hereinafter described.

Turning now to the rest of the device, as illustrated primarily in Figure 1, there are shown arc discharge devices 1 and 2, having anodes 7 and 8, cathodes consisting of mercury pools 4 and 6 and starting electrodes 3 and 5, which latter are each spaced a short distance from surfaces of their respective cathode pools and have their tips each located in a line passing through the centers of the respective cathode pools and perpendicular to the surfaces thereof. This construction is preferable inasmuch as it brings the entire area of the cathode pools as near as possible to being equidistant from the said tip in the normal position of operation of said tubes, but it is not an essential element. These are connected from the source through conductors 30 and 31 and through a load to each other in conventional back-to-back arrangement. The starting electrodes 3 and 5 are each connected through the secondary windings 9 and 10 of conventional peak transformers 13 and 14 to the cathode pools 4 and 6 of the arc devices 1 and 2.

The peak transformers are constructed in a conventional manner and each consists of at least two windings having a small core area with the laminations thereof being separated by a small air gap. The magnetic lines break through the air gap in an appreciable amount and only the highest peak of the current wave, thus causing a transfer from the primary winding to the secondary winding to take place in an appreciable amount at only a limited portion of the sine

wave representing the applied voltage. This is shown in Figure 2 wherein the solid line represents the output of the peak transformer and the broken line 25 represents the voltage applied to the primary winding thereof. The peaks 20 and 21 illustrate the points at which the magnetic flux breaks through the air gap in the peak transformers.

A phase shift circuit is provided for supplying the primary windings 11 and 12 of said peak transformers. Said circuit here for illustration includes a capacitor 15, a variable resistor 16 and the secondary winding 32 of the transformer 17. The center tap 33 is taken from said secondary winding 32 of the transformer 17 and acts as one terminal 34 of said phase shift circuit, and a point 35 between said capacitor and said variable resistor constitutes the other terminal of said phase shift circuit. Said transformer 17 includes a primary winding 36 which is connected through the switch 18 to the A. C. source. It is understood that this switch may be of any effective type and may consist of an electronic circuit as well as being a switch of a mechanical or magnetic type.

The arc-back preventing circuit, being alternative, is illustrated separately in Figure 4. Though specifically illustrated with respect to arc discharge device 2 and transformer 14, it will, where used at all, be similarly applied also to arc discharge device 1 and transformer 13. It consists of a rectifier 22 and a small semi-conductor 23 connected in series with each other and disposed between the cathode of the arc discharge device and a point on the secondary winding of each of the transformers 13 and 14 which point is intermediate the ends of said windings. This semi-conductor is of a conventional type, one being commercially distributed by the General Electric Company under the name of "Thyrite."

It will be understood that the means supplying starting potential to the starting electrode must be of such capacity that it will effect a dielectric break-down, i. e. ionization, of the atmosphere in said arc discharge device. After such break-down is initiated, sufficient ions are formed to continue conduction so long as potential exists between the principal electrodes. Thus, only an initial break-down is required to start conduction, which will then carry through until the current is turned off or until the particular half cycle of the supply current has been completed.

Thus far, in this description, the duration of the current flow between the starting electrode and the cathode pool has been referred to merely as for a very short period. More specifically, it is at least as long as, but not materially longer than, the ionization time of the particular gas comprising the atmosphere in the chamber of the discharge device. Since a period of 100 micro-seconds will suffice for all presently used gases in cold cathode discharge devices, the peak output of the peak transformer will normally be sufficient for all gases which are likely to be used when it extends for a period of 100 micro-seconds.

OPERATION

Referring first to the arc discharge device itself, it will be understood that if a potential of relatively high value be placed across the starting electrode and the cathode pool and, even though it be of extremely short duration, it will effect ionization of some of the molecules comprising the atmosphere within said electric discharge device. With ionization thus started, flow of current is permitted to take place between the principal electrodes, complete the ionization of said atmosphere, and continue for so long as a potential exists therebetween.

With respect to the particular circuit disclosed as made possible by the starting device thus described, alternating potential is supplied from the source of the transformer 17, thence through the phase shift circuit to the primary windings 11 and 12 of the peak transformers 13 and 14. The output of said peak transformers will be of extremely short duration as indicated by the peaks 20 and 21 in Figure 2. The potentials thus supplied to the starting electrodes 3 and 5 and will be of sufficient magnitude to initiate conduction, which, once started will continue for so long thereafter as potential remains between their respective anodes and cathodes.

Thus, after the supplying of a starting potential to the starting electrodes, the electric arc devices will continue to conduct for the balance of the cycle in the source which is being applied to its anode and cathode at the moment the starting potential appears at the starting electrode. Therefore, by utilizing the phase shift circuit to change the phase relationship of the output of the peak transformers with respect to the source potential, the electric arc discharge devices can be caused to conduct for whatever portion of the source cycle is desired. This is illustrated in Figure 3–A, wherein the peaks 20 and 21 are shown as being near the beginning of the source cycles, which cycles are indicated by the line 19, and Figure 3–B illustrates the condition wherein the peaks 20 and 21 appear near the mid-point of the source cycles. In each of the parts A and B of Figure 3, the portion of the source cycles during which the electric arc devices are conducting is shaded. Thus, it can be readily seen that by the shifting of the phase relationship between the output of the peak transformers and the source potential, the average current supplied to the load is readily and accurately controlled.

It will be further appreciated that the herein disclosed circuit for initiating a flow of current through the load circuit will commence operation upon the closing of the switch 18 and will cease operation upon the opening of said switch, and that no other switch, or other control, is actuated to start or terminate the controlled flow of such current.

The polarity of the rectifier 22 is such that on the negative cycles with respect to each electric arc device, the starting electrode and the cathode pool is short circuited and there is no possibility of ionization occurring during these half cycles. However, on the positive cycles, the rectifier, together with the semi-conductor, whose resistance is high when the potential drop across same is low, will insure against passage of current through this shorting path on the positive cycles, and thereby insure the effective imposition of the necessary potential between the starting electrode and the cathode pool to initiate ionization.

It will also be observed that by proper phasing of the starting potential with respect to the principal potential, this device may function as a rectifier.

Modifications of Figures 5 and 6

Figures 5 and 6 illustrate one desired modification of the circuit shown in Figure 1 for producing a high voltage pulse at the starting electrodes

of the electric discharge devices 1 and 2. There are, of course, still other acceptable circuits for this same purpose and this further illustration of such means is not to be construed as limiting but as a further extension of the disclosure.

Turning now to Figure 5, all of the parts having reference numerals identical with the reference numerals in Figure 1 are identical with the corresponding parts in Figure 1, function identically and hence need no separate or further description beyond that given above. However, with respect to the circuit connecting the secondary winding 32 of the transformer 17 with the electric discharge devices 1 and 2 there is in Figure 5 shown an entirely different circuit which will now be described.

There is provided between the terminals 34 and 35 of the phase shift circuit a pair of thyratrons connected in parallel and of reversed polarity with respect to each other, each being associated with a capacitance and a transformer primary winding in series in its anode circuit and both thereof being in parallel with a controllng capacitance.

More specifically, the terminal 35 is connected to the cathode of the thyratron 40 and is also connected through the small capacitance 41 to the grid of said thyratron. The filament of said thyratron is connected through a small resistance 42 to the grid of said thyratron. In a known manner, the values of said capacitance 41 and resistance 42 are selected to effect conduction by said thyratron at a predetermined interval of time following energization at the terminal 35. The anode of said thyratron is connected to one side of the capacitance 43 and the other side thereof is connected to one end of the primary winding 44 of a transformer 45. The other side of said primary winding is connected to the terminal 34. The secondary winding 46 of said transformer 45 is connected at its one end to the liquid pool cathode 4 of the electric discharge device 1 and the other side thereof is connected to the starting electrode 3.

The terminal 34 is connected to the thyratron 50 and is also connected through the small capacitance 51 to the grid of said thyratron. A small resistance 52 is connected between the filament of said thyratron and the grid thereof. In a known manner, the values of said capacitance 51 and resistance 52 are chosen to effect conduction in said thyratron at a predetermined interval of time following energization of the terminal 34 which interval will be the same as that similarly selected for thyratron 40. The anode of the thyratron 50 is connected to a capacitance 53 and the other side thereof is connected to one end of the primary winding 54 of the transformer 55. The other end of said primary winding 54 is connected to the terminal 35. The secondary winding of the transformer 55 is connected to the cathode pool 6 of the electric discharge device 2 and the other side of the primary winding is connected to the starting electrode thereof.

Both said capacitance 43 and said capacitance 53 have connected in parallel therewith high resistances 47 and 57, respectively, to permit discharge thereof during their respective inactive cycles. Also connected between said terminals 34 and 35 is the controlling capacitance 60.

Referring now to the operation of this circuit, the overall operation is the same as above described for the circuit shown in Figure 1 and the difference is only in the manner in which a high voltage pulse is generated and imposed onto the starting electrode 3. As a potential appears between the terminals 34 and 35, the capacitor 60 becomes charged. As the charge on the capacitor 60 builds up towards its peak, and a corresponding potential builds up on the cathode of the thyratron 40, the capacitor 41 and the resistor 42 initially control the grid of said thyratron to prevent conduction therethrough. As the peak charge is attained in the capacitor 60, the simultaneous leakage through the resistor 42 permits the thyratron 40 to fire and, preferably, this occurs immediately upon the attainment of peak charge by said capacitor 60. Current now flows through said thyratron 40 and charges the capacitor 43. As the capacitor 43 charges there is a very brief current caused to pass through the primary winding 44. This causes a current of high value but of extremely short duration to energize the transformer 45 and thus to place a potential of high value but short duration to the starting electrode 3.

On the opposite cycle of the potential appearing at the terminals 34 and 35, a pulse passes in a similar manner through the circuit including the thyratron 50 and is ultimately similarly imposed onto the starting electrode 5. The function of the capacitor 60 is to assist the source for the starting electrode circuit, namely, the secondary winding 32, to pass a maximum amperage through the pulsate circuit in order to attain a very high voltage at the starting electrode.

Referring now to Figure 6, the line 61 indicates the potential at the capacitor 60. The line 62 indicates the corresponding potential at the grids of the respective thyratrons. The line 63 indicates the potential applied at the terminals 34 and 35. The line 64 shows the potential imposed onto the primary windings 44 and 54. Fluoroscopic investigation of these potentials indicates that the duration of the pulse indicated by the line 64 is of the order of 50 or 60 micro-seconds. This value, however, should be taken as illustrative of the operation of the apparatus and not as limiting.

Examining this graph shows that due to the 90 phase shift effected by the capacitor onto the grid of the thyratron 40 with respect to the potential supplied at the terminal 35, the said grid potential returns to zero, or sufficiently near thereto as to permit conduction of said thyratron, at the time that the charge of the capacitor 60 is at its maximum value, whereupon the thyratron 40 conducts and a current of relatively high value flows for an instant through the primary winding 44 and then terminates. Immediately upon the flow of current through the primary winding 44, a potential is placed onto the starting electrode 3 and current flows through the electric discharge device 1 as indicated by the shaded portion of Figure 6, for the balance of the cycle. In this particular instance, the phase shift circuit causes the peak of charging in the capacitor 60 to occur at the same moment as the peak of the supply in the main lines 30 and 31. By shifting said phase shift circuit, this point may be caused to occur elsewhere with respect to the main line sine wave and the period of conduction through the electric discharge device 1 may thus be caused to take place anywhere in the second 90 degrees of said main line sine wave.

It will be understood that the operation of the circuit including the thyratron 50 and the electric discharge device 2 may be as illustrated in the second 180 degree portion of the axis A (Figure 6) in the same manner but with reversed polari-

ties as that described above for the first 180 degree portion thereof.

Modification of Figure 7

Figure 7 shows a capacitor 38 appearing in series with the primary winding 36 of the transformer 13. This is for the purpose of introducing a 90 degree lead into the potential imposed onto the primary winding with respect to the potential imposed by the main lines 30 and 31 onto the electric discharge devices 1 and 2.

In this manner, it is possible to create the starting potential of the starting electrodes 3 and 5 at substantially any point in the cycle pertaining to each thereof rather than only at a point in the last half of said respective cycles. It is thus possible to secure a longer current flow through the load, where desired, by initiating same in the first half of each of said cycle than is possible where said starting potential can occur only in the last half of each of said respective cycles.

This modification may be applied to either of the circuits shown foregoing.

I claim:

1. A device for initiating and terminating the flow of current through a load circuit, comprising: an alternating source of potential; a first transformer, the primary winding thereof being connected to said source, a switch selectively interrupting the energization of said primary winding; a variable resistor and a capacitor and means connecting same in series with each other and means connecting said capacitor in series with one end of the secondary winding of said transformer and means connecting said variable resistor in series with the other end of said secondary winding; a first high voltage pulse producing circuit; means connecting one energizing end of said pulse producing circuit to a point intermediate said capacitor and said variable resistor and means connecting the other energizing end of the pulse producing circuit to a point intermediate the ends of the secondary winding of said first transformer; a second pulse producing circuit and means connecting one of its energizing ends in parallel with, but in reversed polarity to, the corresponding ends of said first pulse producing circuit; a pair of electric arc discharge devices each having an anode and a liquid pool cathode spaced from said anode, and each having a starting electrode positioned intermediate said anode and said cathode means and spaced from each thereof; means connecting said electric arc discharge devices in back-to-back relationship with each other and means connecting said electric arc discharge devices, said source of alternating potential and said load in series relationship; said pulse producing circuits including a pair of thyratrons connected in opposite polarity and each having a capacitor and the primary winding of a transformer in series in the anode circuit thereof, a resistor in parallel with each of said last-named capacitors, the secondary of each of said last-named transformers being connected to the starting electrode and to the cathode pool of each, respectively, of said electric arc discharge devices; and one of said energizing ends of said pulse producing circuit comprising a point between the cathode of one of said thyratrons and the primary winding in the anode circuit of the other of said thyratrons and the other of said energizing ends comprising a point between the cathode of the other of said thyratrons and the primary winding of the anode circuit of said one of said thyratrons.

2. A device for initiating and terminating the flow of current through a load circuit, comprising in combination: a source of alternating potential; a first transformer, the primary winding thereof being connected to said source, a switch selectively interrupting the energization of said primary winding; a phase shift circuit connected to each end of the secondary winding of said transformer; a first high voltage pulse producing circuit; means connecting one input end of said pulse producing circuit to one output terminal of said phase shift circuit and means connecting the other input end of said pulse producing circuit to the other output terminal of said phase shift circuit; a second pulse producing circuit and means connecting the input ends of said second pulse producing circuit in parallel with the corresponding ends of said first pulse producing circuit but arranged in reverse polarity; a pair of electric discharge devices each having an anode and a liquid cathode and each having a starting electrode positioned intermediate said anode and said cathode; means connecting said electric discharge devices in back-to-back relationship with each other and means connecting said electric discharge devices, said source of alternating potential and said load in series relationship; and said pulse producing circuits including a pair of thyratrons connected in opposite polarity and each having a capacitor and the primary winding of a transformer in series in the anode circuit thereof, a resistor in parallel with each of said last-named capacitors, the secondary of each of said last-named transformers being connected to the starting electrode and to the cathode pool of each, respectively, of said electric arc discharge devices, and one of the input ends of said pulse producing circuits comprising the cathode of one of said thyratrons and the primary winding in the anode circuit of the other of said thyratrons and the other of said input ends comprising a point between the cathode of the other of said thyratrons and the primary winding of the anode circuit of said one of said thyratrons.

3. A device for initiating and terminating the flow of current through a load circuit, comprising in combination: a source of alternating potential; a first transformer, the primary winding thereof being connected to said source; a phase shift circuit connected to each end of the secondary winding of said transformer; a pair of electric arc discharge devices, each having an anode and a liquid cathode; and each having a starting electrode positioned intermediate said anode and said cathode; a first high voltage pulse producing circuit including a second transformer, a thyratron, and a capacitor, and the primary winding of said second transformer being in series in the anode circuit of said thyratron, a first resistor in parallel with said last-named capacitor and the ends of the secondary winding of said second transformer being connected to the starting electrode and to the cathode pool of one of said electric arc devices, one input end of said pulse producing circuit comprising the cathode of said thyratron and the other input end comprising that end of the primary winding of said second transformer which is remote from said thyratron; means connecting one input end of said pulse producing circuit to one output terminal of said phase shift circuit and means connecting the other input end of said pulse producing circuit to the other output terminal of said phase shift circuit; a second pulse producing

circuit including a third transformer, a second thyratron and a second capacitor and the primary winding of said third transformer being in series in the anode circuit of said second thyratron, a second resistor in parallel with said second capacitor, the ends of the secondary winding of said third transformer being connected to the starting electrode and to the cathode pool of the other of said electric arc discharge devices, one input end of said last-named pulse producing circuit comprising the cathode of said second thyratron and the other input end comprising that end of the primary winding of said third transformer which is remote from said second thyratron, and means connecting one input end of the said second pulse producing circuit in parallel with the corresponding input ends of said first pulse producing circuit with the thyratrons thereof in opposite polarity and means connecting said electric arc discharge devices in back-

to-back relationship with each other and means connecting said electric arc discharge devices, said source of alternating potential and said load in series relationship.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,995,810	Klemperer	Mar. 26, 1935
2,146,610	Westendorp	Feb. 7, 1939
2,157,812	Bedford	May 9, 1939
2,160,688	Teare	May 20, 1939
2,182,633	Klemperer	Dec. 5, 1939
2,340,061	Knowles	Jan. 25, 1944
2,354,031	La Forge	July 18, 1944
2,359,181	Willis	Sept. 18, 1944
2,468,037	Clark	Apr. 26, 1949
2,484,565	Herskind	Oct. 11, 1949
2,537,767	Langenwalter	Jan. 9, 1951